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July 1927 Entomological Series Vol. X, Nos. 1, 2

Memoirs of the Department of Agriculture in India

1. Four New Indian Gall Midges

BY

E. P. FELT, D.Sc.
State Entomologist, New York

2. The Citrus Psylla (Diaphorina citri, Kuw.) [Psyllidae: Homoptera]

BY

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FOUR NEW INDIAN GALL MIDGES.

BY

E. P. FELT, D.Sc.,

State Entomologist of New York.

(Received for publication on 9th August 1926.)

The descriptions of the following interesting specimens are based upon a small collection of gall midges received from Rao Sahib Y. Ramachandra Rao, Acting Government Entomologist of Coimbatore, South India, under date of 17 March 1926. These rearings add materially to our knowledge of the biology of Indian species.

Dasyneura mangiferae, n. sp.

A series of midges was reared from galls in mango flowers and labelled Coimbatore, South India, 8 February 1924, Y. R. Rao Coll. The species presents marked peculiarities for the genus and, since nothing of the kind has been reared from mango and comparatively few species of this genus characterized from India, it is described below.

Female : Length 1·25 mm. Antennæ extending to the base of the abdomen, sparsely haired, dark brown, 14 segments, the fifth cylindrical, with a length ¾ greater than its diameter, the terminal segment slightly produced, with a length about twice its diameter, broadly rounded apically ; palpi, first segment subquadrate, the second slender, with a length 4 times its diameter, the third ½ longer than the second, somewhat more dilated, the fourth as long as the third ; mesonotum dark reddish-brown, scutellum pale yellowish, postscutellum yellowish-brown ; abdomen dark yellowish-brown ; wings hyaline, subcosta uniting with the margin at the basal half, the third vein well before the apex, the fifth joining the posterior margin at the distal fourth, its branch at the basal half ; halteres pale yellowish ; legs mostly pale straw, the distal tarsal segments darker, the pulvilli as long as the well developed unidentate claws ; ovipositor yellowish, as long as the body, the basal segment, probably the ninth, with a quadrate, median, chitinous plate, with broad, tooth-like, sublateral processes posteriorly, terminal lobes narrowly triangular, with a length about twice the major width, thickly clothed apically with short, stout setæ.

Type A 3452, N. Y. State Museum.

Schizobremia malabarensis, n. sp.

A series of midges was reared from a mealy bug, *Pseudococcus virgatus*, and labelled : On pepper, Taliparamba, N. Malabar, 15 November 1924. A. G. R. Coll.

The species is apparently related to the Formosan *S. formosana*, Felt, and is tentatively referred to the same genus.

Male: Length 1·25 mm. Antennæ about $\frac{3}{4}$ the length of the body, rather thickly haired, fuscous yellowish, probably 14 segments, the fifth with stems $\frac{1}{4}$ and $1\frac{1}{4}$ the length of their diameters respectively, the basal enlargement subglobose with a subbasal whorl of rather long stout setæ and a subapical circumfilum, the distal enlargement broadly pyriform, with a length $\frac{1}{4}$ greater than its diameter, subbasal and subapical circumfila, the loops moderately numerous and long and near the middle a moderately thick whorl of long stout setæ; terminal segment missing. Palpi, first segment with a length about 3 times its width, the second short, with a length about equal to its diameter, the third fusiform, with a length 4 times its diameter; mesonotum a variable fuscous yellowish, scutellum and postscutellum yellowish, abdomen fuscous yellowish; wings hyaline, subcosta uniting with the margin at the basal third, the third vein at the apex of the wing, the fifth joining the posterior margin at the distal fourth, its branch at the basal third; halteres whitish, fuscous basally; legs mostly pale straw, the pulvilli as long as the well developed, strongly curved claws, the latter unidentate on the anterior and mid tarsi. Genitalia, basal clasp segment moderately long, stout, terminal clasp segment rather short, slightly curved and tapering, dorsal plate deeply and triangularly emarginate, the lobes tapering to an irregularly rounded apex; ventral plate long, broad, broadly rounded apically.

Female: Length 1·25 mm. Antennæ extending to the base of the abdomen, sparsely haired, 14 segments, the fifth with a stem about $\frac{1}{4}$ the length of the cylindrical basal enlargement, the latter with a length about $\frac{1}{4}$ greater than its diameter and with thick whorls of rather long stout setæ basally and apically, terminal segment somewhat produced, with a length nearly 3 times its diameter, narrowly and irregularly rounded apically. Palpi, first segment short, subquadrate, the second with a length over twice its diameter, the third a little longer and more slender than the second; ovipositor short, the terminal lobes narrowly oval, with a length about twice the width and sparsely haired. Other characters practically as in the male.

Type Cecid. A 3451, N. Y. State Museum.

LOPESIELLA POLLINIAE, n. sp.

The one female was reared from shoot galls in *Pollinia argentea*, a grass collected at Taliparamba, Malabar, South India, September 1925, Y. R. Rao collector. The reference to this African genus is tentative. Later studies may demonstrate the necessity of erecting a new genus for this species, though this may well be deferred until males are available for study.

Female: Length 3·5 mm. Antennæ $\frac{3}{4}$ the length of the body, rather thickly haired, yellowish-brown, 14 segments, the fifth with a stem $\frac{1}{3}$ the length of the sub-

cylindrical basal enlargement, the latter with a length fully 3 times its diameter, a distinct constriction near the basal third, rather thick whorls of long setæ subbasally and subapically, circumfilar loops only moderately developed. Palpi, first segment short, quadrate, the second slender, with a length 4 times its diameter, the third greatly prolonged, rather slender, with a length 10 times its diameter; mesonotum a variable purplish-brown, the posterior median area and the scutellum yellowish, postscutellum darker, abdomen reddish, sparsely haired; the wings with a distinct yellowish cast, the third vein uniting with the margin well beyond the apex; halteres yellowish-orange; coxæ reddish, legs mostly dark straw, claws long, slender, strongly curved, the pulvilli rudimentary; ovipositor short, stout, the dorsal processes slender, finger-like, with a length 4 times the diameter, the terminal lobes narrowly triangular and sparsely setose.

Exuviae: Length 4 mm. Mostly whitish, the antennal cases extending to the base of the abdomen, the wing cases to the second abdominal segment and the leg cases to the fifth abdominal segment; basal antennal processes conical, chitinized, fuscous apically and with a secondary smaller tooth mesially and basally, the dorsum of the abdominal segments slightly chitinized, yellowish and with irregular transverse rows of subconical processes, these latter being larger on the median posterior line; terminal segment irregularly rounded.

Type Cecid. A 3455, N. Y. State Museum.

Cecidomyia malabarensis, n. sp.

One brightly marked, good-sized midge suggestive of *Lestodiplosis*, Kieff., were it not for the simple claws, was labelled: From pepper berries, 20 October 1925, Taliparamba, N. Malabar, A. G. R. Coll. This insect presumably belongs in the Trifili and owing to practical difficulties in making a definite generic assignment, it is described as new under this very general generic designation, since the striking characters make it relatively easy to establish the identity of the insect later. It is probably an inquiline or predaceous, rather than a true gall producer.

Female: Length 3 mm. Antennæ nearly as long as the body, thickly haired, dark brown, 14 segments, the fifth with a stem $\frac{1}{3}$ the length of the subcylindrical basal enlargement, the latter with a length about $2\frac{1}{2}$ times its diameter, distinctly constricted near the middle and with thick whorls of long stout setæ basally and apically; terminal segment produced, the basal portion cylindrical, with a length 4 times its diameter, the distal part a slender, finger-like process, with a length fully 5 times its diameter. Palpi, first segment short, sub-quadrate, the second slender, with a length 4 times its diameter, the third as long as the second, rather slender, the fourth a little longer than the third, somewhat dilated; mesonotum dark brown, scutellum pale yellowish, postscutellum yellowish-brown; abdomen dark brown, yellowish apically, rather thickly haired; wings subhyaline, fuscous, with a broad, irregular, yellowish band near the distal third, a yellowish area on the basal third of

costa and an indeterminate yellowish or paler area at the distal fourth and also at the apex of the wing ; subcosta uniting with the margin near the basal third, the third vein well beyond the apex, the fifth obsolescent distally ; halteres pale yellowish orange; coxæ mostly yellowish-orange, femora dark brown, the anterior narrowly annulate with yellowish apically, the mid and posterior broadly yellowish near the middle and narrowly so apically ; tibiæ dark brown, the anterior narrowly annulate with yellowish basally, broadly so near the basal third, the mid tibiæ narrowly annulate with yellowish basally, the posterior tibiæ broadly annulate with yellowish basally and at the distal third ; anterior and mid tarsi dark brown, the second segment broadly annulate with fuscous yellowish near the middle, the third and fourth broadly annulate with yellowish basally, the fifth yellowish, the posterior tarsi with the first segment fuscous, the second yellowish with its distal third fuscous, the third and fourth yellowish with the distal half dark brown, the latter somewhat lighter, the fifth yellowish, claws fuscous, rather strongly curved, unidentate, the pulvilli rudimentary ; ovipositor short, the terminal lobes broadly, irregularly triangular and with a long dorsal seta near the middle, a group of setæ apically and on the ventral margin near the middle a somewhat diffuse group of smaller setæ.

Type Cecid. A 3453, N. Y. State Museum.

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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1

1c

1a

1b

2

3

4

7

7a

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5

6

Diaphorina citri (Citrus Psylla).

PLATE I.

Diaphorina citri (Citrus Psylla).

1. Groups of eggs *in situ*.
1*a*. Egg, side view.
1*b*. Egg, front view.
1*c*. Eggs with stalks inserted in plant tissue.
2. First stage nymph.
3. Second stage nymph.
4. Third stage nymph.
5. Fourth stage nymph.
6. Fifth stage nymph.
7, 7*a*. Adults : colour varieties.
8. Different stages on citrus shoot.
9. An attacked plant showing dried up twigs.

THE CITRUS PSYLLA (DIAPHORINA CITRI, KUW.) PSYLLIDAE: HOMOPTERA.

BY

MOHAMMAD AFZAL HUSAIN, M.Sc., M.A.,
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INTRODUCTORY.

Of the Insect Pests of Citrus in India, *Diaphorina citri*, Kuw., commonly known as the 'Citrus Psylla,'* is of the greatest importance. It is present all over the country and has been so abundant in many localities as to call for special attention. In certain tracts in the Punjab it has been responsible for very serious losses. In one particular instance, a Citrus orchard which was normally leased for Rs. 2,000 per season yielded no more than Rs. 100 after an attack of this pest lasting for a couple of years. It is not an uncommon sight to see once valuable orchards reduced to unproductive plantations of dried skeletons of trees, primarily through the ravages of this insect (Pl. I, fig. 9).

This pest has been under observation for the last six years, both in the laboratory and under orchard conditions, and details of its structure, life-history, bionomics and control are presented in this paper. Crawford[1] and Ferris[2] have deplored the absence of detailed studies of the larval stages of Psyllids, and the importance of such accurate descriptions of the early stages as would permit of positive identification of insects cannot be overestimated in the case of pests. Valuable contri-

* In the Punjab this insect is commonly referred to as *taila* or *chaipak*. These terms are, however, very misleading, as they are applied indiscriminately to all those insects which secrete honey-dew. This sugary substance, falling on the leaves, gives them a shining appearance, as if smeared with oil, hence the term *taila* (*tail*: oil), and imparts to them a certain amount of stickiness, hence the term *chaipak* (*chaipak*: stickiness). All insects which belong to the families Fulgoridae, Jassidae, Psyllidae, Aphididae Aleyrodidae and Coccidae are spoken of as *taila* or *chaipak*.

[1] Crawford, D. L. (1914) A monograph of the Jumping Plant-lice or Psyllidae of the New World. *United States National Museum, Bull.* 85.

[2] Ferris, G. F. (1923, 1925, 1926) Observations on the Chermidae. *Canadian Entomologist*, LV, pp. 88-92, 250-256, LVII, pp. 46-50, LVIII, pp. 13-20.

butions to the study of the external morphology of the nymphal stages of a number of Psyllids have been made by Ferris[1], and the description of the immature stages of *D. citri*, with such details of the external features of the adult as may be useful, are included in this paper. Field observations and experiments which

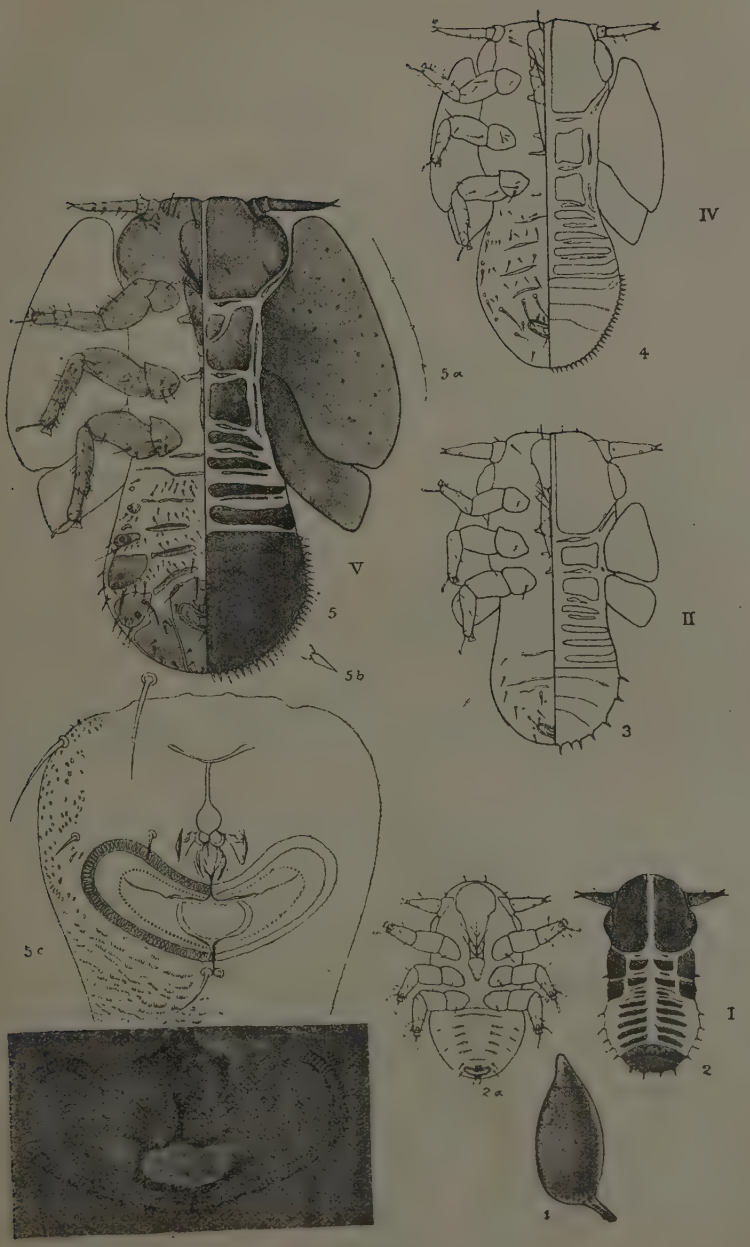
Fig. 1. Attacked orchard : note dried branches.

form Part II of this paper were carried out by the junior author under the guidance of the senior author. For the description of the various stages and the preparation of the paper for the press, the senior author is entirely responsible. This work was carried out during his tenure of office at the Agricultural Research Institute, Pusa.

Field investigations were carried out chiefly at Sargodha, Lyallpur and Gujranwala in the Punjab, and supplemented with observations from other parts of the Province, and confirmed by studies undertaken by the senior author at Pusa. The conclusions drawn will apply, with slight modifications, to other parts of India.

The photograph (Pl. II. fig. 5 *d*.) of the anal region of the nymph was taken by Mr. J. H. Walton, the Imperial Agricultural Bacteriologist, to whom our thanks are due for this help.

[1] Ferris, G. F. (1923, 1925, 1926) Observations on the Chermidae. *Canadian Entomologist*, LV, pp. 88-92, 250-256, LVII, pp. 46-50, LVIII, pp. 13-20.



Diaphorina citri (Citrus Psylla).

PLATE II.

Diaphorina citri.

1. Egg, side view.
2. First stage nymph, showing sclerites of derm, dorsal view.
2*a*. First stage nymph, ventral view.
3. Second stage nymph, dorsal and ventral views.
4. Fourth stage nymph, dorsal and ventral views.
5. Fifth stage nymph, dorsal and ventral views.
5*a*. Margin of wing-pads, showing clavate setæ.
5*b*. A lanceolate seta enlarged.
5*c*. Anus with circum-anal rings, highly magnified.
5*d*. Photograph of the anal region. (Anus is the lighter oval area, the inner pores appear as black dots, visible in places, and the outer ring of gland openings is distinct.)

PART I

SYSTEMATIC POSITION.

D. citri, Kuw., has been placed in the sub-family Psyllinae of the family Psyllidae (Chermidae) [Homoptera]. According to Crawford[1] " the principal and most distinctive characters of this sub-family are the concealed frons (Pl. III, figs. 1, 1*a*, *fr*), the presence of genal cones or lobate processes (*g.c.*), the presence of the apical claw-like spines on the posterior basal tarsus (not limited, however, to this group) (Pl. IV, figs. 3*a*, 3*b*, *ta. cl.*), and the presence of the cubital petiole (M+Cu)" (fig. 6). On the basis of the structure of the adult, *D. citri* certainly belongs to the sub-family Psyllinae, as it possesses very clearly all the above mentioned distinctive characters. A study of the immature stages of this species, however, reveals a different situation, as the nymphs differ markedly from all those that have, so far, been described from the sub-family Psyllinae, while, on the other hand, they bear a very strong resemblance to those of the sub-family Triozinae.

Crawford,[1] ' for convenience,' divides the subfamily Psyllinae into four tribes, and Ferris[2] has studied the immature stages of the representatives of all these tribes :—

Tribe Pachypsyllini—*Pachpsylla venusta*, Osten Sacken.
Tribe Euphyllurini—*Euphyllura arbuti*, Schwarz.
Tribe Arytainini—*Psyllopsis fraxinicola*, Foerster.
Tribe Psyllini—*Psylla alni*, Linn., *P. buxi*, Linn.

The nymphs of the later stages of all these species agree in being of the typical Psylline type[2]—the form in which the wing-pads are not produced cephalad at the humeral angle but project prominently from the contour of the body. The nymphs of *D. citri*, at any rate, the stages with wing-pads, do not resemble any of the above as the wing-pads are strongly produced cephalad at the humeral angle, and the nymphs therefore belong to the Triozine type[2]. They come very close to the nymphs of *Paratrioza cockerelli*, Sulc.,[2] not only in the general form of the body and the cephalad prolongation of the wing-pads at the humeral angle, but also in the form and segmentation of the antenna—which are not more than 3-jointed even in the fifth stage nymphs, the structure of the legs and arrangement of the circum-anal pore-ring Other nymphs of the sub-family Triozinae, which have so far been described, *e.g.*, *Trioza urticae*, Linn., *Phyllopecta dispyri*, Ashmead, and *Ph. tripunctata*, Fitch, are all modelled after the same pattern[2] and agree with the nymphs of *D. citri*. Even *Ceropsylla sideroxyli*, Riley,[2] which belongs to the Triozinae,

[1] Crawford, D. L. (1914) A monograph of the Jumping Plant-lice or Psyllidae of the New World. *United States National Museum, Bull.* 85.
[2] Ferris, G. F. (1923, 1925, 1926) Observations on the Chermidae. *Canadian Entomologist*, LV., pp. 88-92, 250-256, LVII, pp. 46-50, LVIII, pp. 13-20.

can easily be recognised as an exaggerated form of the same type—the Triozine type of Ferris.

In short, the nymphal affinities of *D. citri* suggest a closer relationship with the sub-family Triozinae rather than with the sub-family Psyllinae. A further study of the nymphs of the family Psyllidae is necessary to clear this point.

Franz Low[1] (1878) erected the genus, to which this insect belongs, as *Diaphora* ; but, as the name was preoccupied in Lepidoptera, he changed it to *Diaphorina* in 1879.

Crawford[2] gives the following distinctive characteristics of the genus *Diaphorina* Low :—

> "Antennæ very short, about as long as width of head or less, moderately thick. Genal cones thick, porrect (extending forward in same plane with vertex or nearly so). Thorax moderately narrow and slender, dorsal surface more or less granulate (gekornelt). Fore wings long, broadest near the apical end, basal half narrow ; membrane more or less hyaline and usually maculated extensively with brown ; pterostigma very narrow or wanting."

Synonymy.

Diaphorina citri, Kuwayama, *Trans. Sapp. Nat. Hist. Soc.* ; II, 160 (1907).
Euphalerus citri Crawford, *Rec. Ind. Mus.*, VII, 424 (1912).
Diaphorina citri, Kuw. *Rec. Ind. Mus.*, XXVI, 616 (1924).

DISTRIBUTION.

Diaphorina citri, Kuw., is widely distributed throughout the Orient.[3] It is known from Formosa, the Philippine Islands, Moluccas (Amboina), Southern China (Macao), and occurs all over India[4]. We have actual authenticated records from Pusa, Adra, Coimbatore and many localities in the Punjab. Specimens, in the collection of the Agricultural Research Institute at Pusa collected by T. Bainbrigge Fletcher at Poona on 8th September 1911, were first identified by Crawford[4] as *Euphalerus citri*, but have since been found by him to belong to *D. guttulata*, Lethierry[2]. Fletcher[5] mentions *E. citri* from Cherat. (N.-W. F. P.), but an examination of this single specimen shows that it is not *D. citri*, the wing pattern being quite different.

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[1] Low, F. (1878, 1879) *Verh. d. zool.-bot. Ges.*, XXVIII, p. 603, XXIX, p. 567.
[2] Crawford, D. L. (1924) *Rec. Ind. Mus.*, XXVI, pp. 615-616.
[3] Crawford, D. L. (1917) *Philipp. Jl. Sc.*, XII, p. 168.
[4] Crawford, D. L. (1912) *Rec. Ind. Mus.*, VII, p. 424.
[5] Fletcher, T. Bainbrigge (1919) *Proc. Third Ent. Meet.* p. 276.

FOOD PLANTS.

D. citri has been found on all the cultivated varieties of *Citrus* and has been actually found attacking the following in the Punjab :—

Botanical name	English name	Local name
Citrus aurantium	Orange	Sangtara, Malta
Citrus medica limonium	Lemon	Limu
Citrus medica lunetta	Sweet lime	Mitha
Citrus medica acida	Sour lime	Khatta
Citrus medica medica	Citron	Galgal
Citrus decumana	Pomelo	Chakotra

D. citri has also been recorded from *Murraya koenigii* (Rutaceae) at Coimbatore, (S. India), and Pusa, and this may be considered as an alternative food plant. [1 2 5] Crawford[3] mentions *Euphalerus citri*, Kuw. as having been collected at Coimbatore by " T. V. R." on *Cardia* and by " C. N." on *Cardia** *cordata* (Boraginaceae), and Fletcher[1] records it from *Cordia cordifolia* from the same locality. But the species found on *Cordia* spp. has since been identified by Crawford[4] as *D. cardiae*. T. V. Ramakrishna Ayyar[6] (1924) does not mention *Cordia cordata* among the plants on which *D. citri*, Kuw. has been found, but on the other hand he records *C. cordata* as the food plant of *D. cardiae*. It may, therefore, be stated that so far *D. citri* has only been found on the plants of the order Rutaceae.

DESCRIPTION OF THE VARIOUS STAGES OF *D. CITRI*.

Egg.

(Pl. I, fig. 1, *a*, *b*, *c* ; Pl. II, fig. 1.)

The egg may be described as almond-shaped, elongate, thicker at the basal end and tapering towards the distal end, where it is slightly curved and ends in a blunt point. From its rounded basal end arises a slender stalk-like process, which serves to anchor the egg, being thrust into the plant tissue. The length of the egg, without the stalk, is 0·3 mm., and the stalk measures 0·038 mm.; the greatest diameter of the egg is 0·13 mm. The colour of a freshly laid egg is pale yellow, but as development of the embryo proceeds, the colour gradually turns orange. A short time before hatching, two red spots—the eyes of the nymph—become visible. The egg shell is smooth and shining and no sculpturing of any description has been noticed. The arrangement of the egg membranes is the same as described for *Psylla mali* by Lees[7], and in general outline also there is a close

* It appears that *Cordia* has been misspelt as *Cardia*, the specific name of this insect may therefore be altered to *cordiae*.

[1] Fletcher, T. Bainbrigge. (1919) *Proc. Third Ent. Meet.*, p. 276.
[2] Fletcher, T. Bainbrigge. (1917) *Proc. Second Ent. Meet.*, pp. 215-16.
[3] Crawford, D. L. (1917) *Philipp. Jl. Sc.*, XII, p. 168.
[4] Crawford, D. L. (1924) *Rec. Ind. Mus.*, XXVI, p. 617.
[5] Ramakrishna Ayyar, T. V. (1923) *Proc. Fifth Ent. Meet.*, p. 267.
[6] Ramakrishna Ayyar, T. V. (1924) *Rec. Ind. Mus.*, XXVI, p. 624.
[7] Lees, A. H. (1916) Some observations, on the egg of *Psylla mali*. *Ann. App. Bio.*, II, pp. 251-57.

resemblance, the only difference being that the solid process at the distal end is absent in *D. citri.**

The eggs are laid on the tender shoots in such large numbers as to impart to them a distinct orange colour.

Nymphal Stages.

To study the sclerites in the derm the nymphs were cleared in a strong solution of KOH, washed, and stained with magenta or eosin. Excellent results were obtained by staining with eosin dissolved in oil of cloves. The stain is not permanent but gives perfect differentiation, all chitinized portions standing out distinctly. To study the details of structure it has been necessary to cut the nymphs horizontally so as to separate the dorsal from the ventral halves. For this purpose nymphs were cleared and stained with eosin in oil of cloves and embedded in paraffin. The superfluous paraffin was then scraped off and the nymphs cut by means of a safety razor blade. The paraffin was dissolved in xylol and the specimen mounted in balsam.

It has been found convenient to give a detailed description of the nymph of the fifth stage and compare with it the other stages.

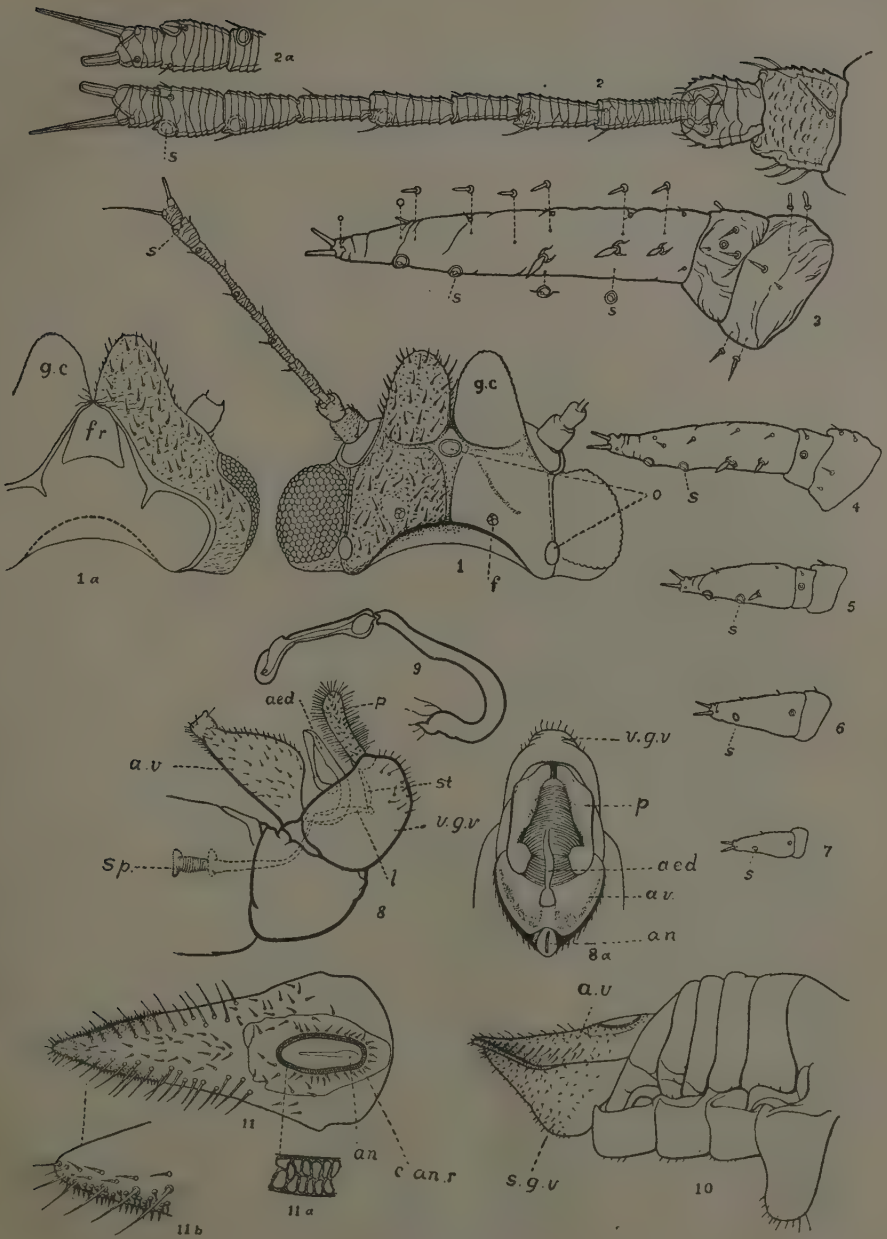
Fifth instar.—(Pl. I, fig. 6 ; Pl. II, figs. 5, 5*a*, 5*b*, 5*c*, 5*d* ; Pl. III, fig. 3 ; Pl. IV, figs. 1, 1*a*.) The general form of the nymph is what has been described by Ferris as *triozine*. This is characterized by the wing-pads being produced cephalad at the humeral angle.

The general colour of the nymph is light yellow with an orange tinge in the region of the abdomen. Some nymphs, however, show a light bluish-green tinge. In a full-grown nymph the antennæ, tips of tarsi, and tip of rostrum are dark, the eyes dark red. The measurements of certain parts of body are given below :—

	mm.
Width of head in the region of the eyes	0·57
Length of antennæ	0·3
Length of mesothoracic wingpads	0·9
Length of tarsal golf-club-shaped setæ	0·07
Total length of the body excluding lanceolate spines	1·6—1·7

The *Head* (Pl. II, 5) is well marked and separated from the thorax by a distinct groove, which is strengthened by narrow chitinous sclerites. The dorsum of the head itself shows two well-developed sclerites separated by a median narrow strip along which the skin splits during moulting. The *Eyes* are quite large but *ocelli* are absent. (In a full-grown nymph the ocelli of the adult appear as pinkish spots visible through the skin of the nymph). The *antennæ* (Pl. III, 3) are quite large, thicker at the base and tapering towards the tip, the basal two joints are distinct

* Brocher, F. (1916) *Ann. Soc. Ent. France*, XCV, pp. 183-188. (Also remarks that the process mentioned by Lees is absent.)



Diaphorina citri (Citrus Psylla.)

PLATE III.

Diaphorina citri (Citrus Psylla).

1. Head of adult, dorsal view. *f.* fovea, *g.c.* genal cones, *o.* ocelli, *s.* sensorium.

1*a*. Head of adult, ventral view. *fr.* frons, *g.c.* genal cones.

2. Antenna of adult, dorsal view. *s.* sensorium.

2*a*. Terminal portion of the antenna of the adult, ventral view.

3. Antenna of fifth stage nymph, dorsal view (structures on the ventral side shown separately and their position indicated by dots). *s.* sensorium.

4. Antenna, fourth stage nymph

5. Antenna, third stage nymph.

6. Antenna, second stage nymph.

7. Antenna, first stage nymph.

8. Abdomen, male, terminal segments, lateral view (lettering as below).

8*a*. Abdomen, male, terminal segments, dorsal view. *aed.* aedeagus, *an.* anus, *a.v.* anal valve, *l.* chitinous loop, *p.* parameres, *sp.* spool, *st.* chitinous strut, *v.g.v.* ventral genital valve (subgenital valve).

9. Aedeagus, much enlarged.

10. Abdomen, female, lateral view. *a. v.* anal valve, *s.g.v.* sub-genital valve.

11. Anal valve of a female, dorsal view. *an.* anus, *c.an.* circumanal ring.

11*a*. Circumanal gland openings, highly magnified.

11*b*. Tip of anal valve of female, highly magnified.

and the remaining portion not differentiated into segments, although some irregular faint lines are noticeable. From the proximal half of the undifferentiated portion of the antenna arise three lanceolate setæ, the most proximal of which is the smallest. During life these setæ are enclosed within cylindrical sheaths of wax similiar to those described for the lanceolate setæ of the abdominal region (see below). There are four sensoria on the ventral side of each antenna. In a cleared specimen the sensoria appear as hollow spheres. Besides these, there is a pit-like structure near the tip of the antenna, and a peculiar structure—which appears like a double ring—on the second joint. These two structures may also be sensory in function. A series of bristles arises from the ventral side of the antenna and its tip is armed with two unequal, thick, hollow bristles arising from separate protuberances. The *Rostrum*, as in the adult, is firmly attached to the sclerite in the region of the prosternum, and is bent at a right angle between the coxæ of the forelegs (in the diagrams it has been shown straightened out).

The *Thorax* (Pl. II, 5) is also distinctly marked and shows definite chitinized areas. The dorsum has three pairs of large sclerites, a pair between the mesothoracic wing-pads and another between the metathoracic wing-pads; the third pair, which is the smallest, is, as it were, cut off from the first pair and is situated in front and near the middle line. Separating the larger sclerites and the wing-pads are narrow strips of chitin.

The *Wing-pads* are very large and well developed and arise from the body by broad bases. The humeral angle is produced forwards reaching the level of the eye. Under very high magnification the surface as well as the margins of the wing-pads show small clavate hairs (figs. 5, 5*a*). Ventrally the thoracic region is soft except for a few thin strips of chitin. Two of these strips are transverse and are situated between the bases of the fore and middle legs, and the third runs longitudinally in the middle line between the middle and hind legs.

The *Legs* (Pl. II, fig. 5) are well developed and each consists of four segments, the trochanter not being differentiated. In all the legs the unjointed tarsus is separated from the tibia by a distinct joint. The end of the tarsus presents some interesting features. From its dorsal aspect just behind the tip arises a single, long, hollow seta, which may be described as golf-club-shaped,* as it has a long shaft and is bent and swollen at the end (Pl. IV, figs. 1, 1*a*, *g. c. s.*). The length of this seta is 0·07 mm. In the fifth stage nymph there is only a single seta on each tarsus. These setæ evidently help in locomotion. If a nymph be observed under a binocular it will be noticed that the swollen end of the seta comes in contact with the surface on which the nymph is walking, and that the end of the seta remains attached to the surface a little after the claws and pulvilli have shifted forwards. These setæ perform this function most probably by means of some sticky secretion. From under the end of the tarsus arises a fairly large fish-tail-shaped pulvillus (*p*),—

* We are indebted to Mr. Khan A. Rahman of the Entomological Section, Agricultural Research Institute, Pusa, for suggesting this very expressive name for this seta.

the basal portion of which has a peg-like supporting structure. On the ventral side of the tarsus are two strongly chitinized median sclerites, the proximal of which has attached to it a long tendon which runs backward and can be traced up to the femur. The distal of these sclerites bears two strong bristles, the seats of origin of which appear as transparent circles. On the side of these median sclerites are the lateral sclerites which provide support for the paired claws.

The *Abdomen* (Pl. II, fig. 5) is well chitinized dorsally but is membraneous ventrally. Four pairs of tergal sclerites can be distinguished and there is a chitinous apical plate composed of four or five pieces ; faint groves on this indicate segmentation. Between some of the anterior tergal sclerites there are thin chitinous strips which are intersegmental in position. Round the margin of the apical plate are a series of lanceolate setæ. Their number varies from 53-60. These setæ vary in size also but those towards the end are the longest and may be as much as 0·02 mm. in length. During life these setæ are covered over with continuously growing, narrow, tubular sheath of waxy secretion. This secretion is produced by the glands situated round the bases of the setæ, and the setæ act as a central support for these small cylinders of wax. The ventral side of the abdomen is membranous except for a few thinly chitinized areas. The most marked of these is the plate bearing the anus and the circum-anal rings of pores and openings of glands. This plate is separated from the two lateral plates by folds, which run obliquely forward and also separate the small chitinous plates surrounding the spiracles from the sternites of the abdomen. The anal opening is well in front of the tip of the abdomen. As mentioned above, the anus is surrounded by a well-marked ring of minute pores (Pl. II, figs. 5*c*, 5*d*), and ornamentally arranged slits in a heavily chitinized area. Both these rings are interrupted anteriorly and posteriorly along the middle line. Two strong bristles are situated close to the posterior edge of the ring, one on each side of the median line.

Fourth instar. (Pl. I, fig. 5, Pl. II, 4) Colouration and general form is the same as in the fifth instar ; besides the size, the following differences may be noted :—

There are only two lanceolate setæ on the antenna, and only three sensoria ; on the thorax only two pairs of dorsal sclerites are present, the smallest pair of the fifth stage not having separated as yet. The tarsi are not separated from the tibiæ.

Third instar. (Pl. I, fig. 4) Colouration slightly more orange ; the general form of the body the same as for the above mentioned stages ; the wing-pads are smaller, the anterior edge of the mesothoracic wing-pads just reaches the eyes ; only the basal joint of the antenna is differentiated and there are only two sensoria and a single lanceolate seta.

Second instar. (Pl. I, fig. 3 ; Pl. II, fig. 3). Colouration and general form is the same as described above ; the wing-pads are small triangular processes projecting from the body, the cephalad growth of the humeral angle is noticeable even at this stage ; there is no lanceolate seta on the antenna and only one sensorium.

First instar. (Pl. I, fig. 2, Pl. II, figs, 2, 2*a*). The nymph in this instar differs considerably from the later stages. Wing-pads cannot be made out, but the chitinous sclerites, which in later stages represent the wing-pads, are quite large. The arrangement of the abdominal sclerites is also very different. There are six pairs of tergites and the apical piece is probably made up of two pairs. Another peculiarity of this stage is that from the dorsal surface of the derm arise a number of setæ. Another feature in which the first-instar nymph differs from all the later stages is the presence of two golf-club-shaped tarsal setæ on each of the middle and hind legs, and a single seta on each of the fore legs (Pl. IV, figs. 2, 2*a*). Further the pulvilli are not fish-tail-shaped but are rounded at their free edges. The antenna is the same as described for the second instar nymph. The anus is nearer the apex of the abdomen than in the later stages. Besides the lanceolate setæ around the abdomen there is one on each side of the thorax.

Comparative statement of the measurement of various parts of D. citri, *during different nymphal stages.*

——	I.	II.	III.	IV.	V.	
Width of head in region of eyes.	0·15	0·24	0·3	0·42	0·57	All measurements in mm.
Length of antennæ without terminal spines.	0·06	0·08	0·12	0·18	0·3	
Length of mesothoracic wing-pads.	..	0·12	0·26	0·5	0·9	
Length of golf-club tarsal seta.	0·022	0·029	0·035	0·05	0·07	
Length of body excluding lanceolate spines.	0·26—0·35	0·43—0·56	0·67—0·72	0·76—1·2	1·6—1·7	
Number of lanceolate spines on the apical plate.	11—14	13—15	22—32	38—57	53—60	

Adult.

(Pl. I, III, IV).

The following is Crawford's[1] description of *D. citri* (*Euphalerus citri*) :—

" Length of body 2·4 mm.; length of fore wing 2·4 mm.; greatest width 1·0 mm.; width of vertex between eyes ·35 mm.; with eyes ·55 mm.; length of vertex to tip

[1] Crawford, D. L. (1912) *Rec. Ind. Mus.*, VII, p. 424.

of cones ·32 mm. General colour brown, vertex slightly lighter ; antennæ black at tip ; eyes darker, with black stripe from eye to tip of cone on side ; forewings with a spotted macula of brown on the upper margin from a little below tip of clavus to tip of radius, and another on lower margin not quite merged into first, maculæ not continuous but composed of smaller scattered spots. Head narrower than thorax, descending ; vertex flat, very finely pubescent, finely punctate, broader than long, with a fovea on each side in rear centre ; anterior margin almost straight ; facial cones broad at base, in same plane with vertex, convergent toward and rounded at apex, almost contiguous, finely pubescent. Antennal bases scarcely visible, as in other species ; antennæ short, not longer than head and pronotum combined, slender. Eyes large."

" Thorax very finely pubescent ; pronotum rather long, sides parallel ; pleurites typical for genus. Fore-wings subhyaline, rather thickened as in other species, maculate, attenuate at base, broadest subapically, rounded at apex, about two and a third times as long as broad ; first cubital long ; second marginal cell larger than first ; radius long ; pterostigma very narrow, quite long."

" Male—Genital segment rather conspicuous ; anal valve elongate-pyriform or flask-shaped, attenuate above ; claspers long, slender, subacute at tip, simple."

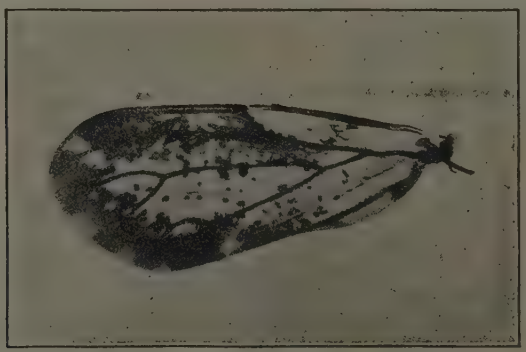


Fig. 2.

Wing of *D. citri*. (Photograph).

" *Female*—Genital segment short, small, acute at tip ; dorsal plate very slightly longer than ventral."

The above description was based on one female from Adra, Manbhum District (previously in Bengal now included in the province of Bihar and Orissa) collected

PLATE IV.

Diaphorina citri (Citrus Psylla).

1. Tarsus, fifth stage nymph, ventral view. *cl.* claw, *g.c.s.* golf club seta, *p.* pulvillus ; i, ii, iii, chitinous sclerites.

1*a*. Tarsus, fifth stage nymph, side view (lettering as above).

2. Tarsus, first stage nymph, ventral view (lettering as above).

2*a*. Tarsus, first stage nymph, side view (lettering as above).

3. Posterior leg of the adult. *ti.s.* tibial spines.

3*a*. Lower part of tibia and tarsus of adult, ventral view. *ta.cl.* tarsal claws ; *ti.s.* tibial spines.

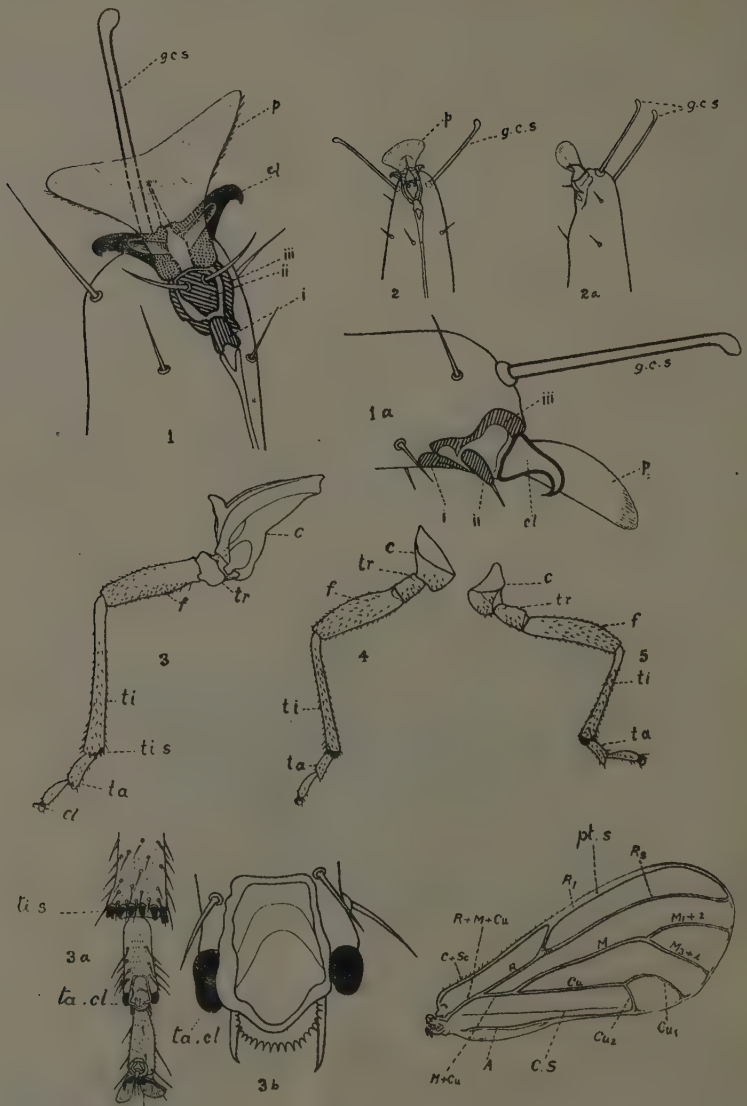
3*b*. Terminal portion of the basal joint of the tarsus, highly magnified, to show the structure of pulvillus-like pad.

4. Middle leg of adult.

5. Fore leg of adult.

6. Fore wing. *pt.s*, pterostigma.

PLATE IV.



6

Diaphorina citri (Citrus Psylla).

by J. T. Jenkins (1909), and seventeen specimens of both sexes from the Philippines collected by George Compere. The description of the male was based on the Philippine specimens. Crawford has since examined more material from India.

The following notes are added to complete the above description and explain the diagrams.

The total length of the insect from the tip of genal cones to the apex of wings is 3·10—3·38 mm.; length of head from vertex to tip of genal cones is 0·28—0·34 mm.: width of vertex between eyes is 0·32—0·36 mm.: and width with eyes is 0·51—0·56 mm.

During life the insect is covered over with a whitish waxy secretion and appears as if dusted with white. The black stripe from eye to tip of genal cone is not distinctly visible in a living specimen but is quite clear in alcoholic material. Further, there is variation in the colour of this stripe ; usually it is greyish, black only in very dark specimens. The colour of the abdomen also varies and appears to depend on the contents of the abdominal regions. It is usually greyish brown, but in some specimens it is distinctly bluish, while in gravid females, particularly during spring, it is distinctly orange.

The total length of the antenna is 0·58 mm., it is 10-jointed, the 3rd joint is the longest. At the distal ends of the 4th, 6th, 8th and 9th joints there are sensoria (Pl. III, figs. 2, 2*a*). The tip of the antenna is armed with two unequal hollow bristles.

The frons is concealed by the genal cones dorsally and is visible ventrally as a large plate (figs. 1, 1*a*).

The first two pairs of legs have fringes of whitish, delicate spines, at the end of tibia, the third pair have eight strong black spines. The tip of the basal joint of the hindmost tarsus has two claw-like spines and between these is a pad-like structure. (Pl. IV, figs. 3*a*, 3*b*).

The terminal segments of the abdomen are greatly modified for reproductive purposes. There exists considerable confusion regarding terminology used and difference of opinions concerning the segments which enter into the composition of these genital organs. The anus-bearing segment, which is known as the anal valve (Crawford)[1] or supra-anal plate (Stough)[2], is according to Witlaczil[3] the tenth segment both in the male and female. Stough[2] agrees with this interpretation and Singh Pruthi[4] holds the same opinion in so far as male Psyllids are concerned. Crawford,[1] however, considers the anus-bearing segment to represent the eleventh

[1] Crawford, D. L. (1914) *United States National Mus. Bull.* 85.
[2] Stough, H. B. (1910) The Hackberry Psylla, *Pachypsylla c.-mamma. Kansas University Sc., Bull.* 5.
[3] Witlaczil (1885) Die anatomie der Psylliden. *Zeit. wiss. Zool.*, XLII.
[4] Singh-Pruthi, H. (1925) The Morphology of the male genitalia in Rhynchota. *Trans. Ent. Soc., London.*

segment in the male and female, the tenth segment being represented by the ovipositor of the female and the boat-shaped (sub-genital plates) segment of the male, in the hollow of which the aedeagus lies and to the posterior margin of which the parameres (Singh Pruthi) or forceps (Crawford) are attached. Witlaczil considers this to be the ninth segment, which is well developed ventrally and unrepresented dorsally. In the female, he considers the sub-genital plate (ventral genital valve) to be the tenth segment.

Male. (Pl. III, figs. 8, 8*a*, *a. v.*). In the male the tip of the abdomen is bent upwards. The anal valve is pyriform and hairy and the anus is carried at its end on a fleshy protuberance. This valve is carried at a right angle to the axis of the abdomen and forms the dorsal and anterior wall of the genital apparatus. The length of the anal valve is 0·36—0·4 mm.; Stough[1] has given a full description of the male genitalia in *Pachypsylla c.-mamma*, and Singh Pruthi[2] has also described these organs in a few Psyllids. The aedeagus (figs. 8, 9) consists of two parts, articulated in such a manner that the distal part is freely moveable, it is more or less straight and swollen slightly and bent at the tip. The cephalic face of the club is hollowed out to form a deep longitudinal groove. Arising from the front end of this grove is a tooth-like structure. The distal part of the aedeagus measures 0·2 mm. The proximal portion of the aedeagus is highly chitinized and strongly armed, it articulates with the base of the anal valve by broad plate-like expansions. The ejaculatory duct enters the aedeagus through the base of the proximal portion. This duct is chitinized and towards its anterior part it presents a spool-like structure (Pl. III, fig. 8). The middle portion of the spool is striated. The length of the spool is 0·066 mm.

Articulating with the base of the aedeagus is a loop of chitin and between the arms of the loop the proximal portion of the aedeagus lies. A median chitinous strut runs from the posterior end of the loop to the junction of the parameres.

The aedeagus and the loop and strut above-described lie in the hollow of the boat-shaped subgenital plate (or valve), which is well chitinized. The two flattened narrow parameres articulate with each other and with the posterior edge of the subgenital plate. Each of the parameres has a strong tooth at its extremity and is set with very long bristles, particularly on the median surface. The parameres are 0·3 mm. long.

Female. The end of the abdomen is not curved upward but is straight, coming to a point. The chitinized portion consists of two valves, the anal valve (supra-anal valve), which is dorsal, and the ventral subgenital valve. The dorsal valve is wedge-shaped and near its tip it is armed with short strong bristles (Pl. III, fig. 11, 11*b*).

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[1] Stough, H. B. (1910) The Hackberry Psylla, *Pachypsylla c.-mamma*. *Kansas University Sc., Bull.* 5.

[2] Singh-Pruthi, H. (1925) The Morphology of the male genitalia in Rhynchota. *Trans. Ent. Soc., London.*

It is 0·7 mm. long. Near its base is a clear area and on this portion is situated the slit-like anus surrounded by an oval ring of a double row of the openings of wax glands. From these openings waxy secretion comes out. This elliptic ring is 0·16—0·2 mm. along its longest axis. The sub-genital valve (ventral valve) is boat-shaped and slightly shorter than the anal valve.

PART II

LIFE-HISTORY.

Many complete life cycles of this insect were studied by sleeving adults on small citrus plants grown in pots and on tender shoots of plants in orchards. Attempts to rear nymphs on twigs cut off from the trees were not successful.

Copulation. Soon after emergence the adults copulate. As the genital segments of the male are turned upwards the male has to approach the female from the side and bend the tip of its abdomen down to the level of the aperture of the female genitalia ; thus a male may be seen in that position holding the female with the legs of one side and supporting itself with the legs of the other side, the heads pointing in the same direction.

Oviposition. Soon after copulation, if tender shoots are available, the female starts laying eggs. The eggs are always laid on fresh growth, usually in the folds of half opened leaves, axils of leaves, pushed in between the buds and stem or petioles of leaves and axillary buds, and other similar situations. They are also laid scattered about on the upper or lower surfaces of the leaves and on tender stem. It may be stated that the females will not lay eggs on older tough leaves or stems even in the absence of tender shoots. The stalk of the egg is thrust into the tissue of the plant and the egg is firmly held in position. In some cases, however, particularly when too many eggs have been laid at the bottom of a folded or half opened leaf, a few of the eggs appear to lie loose, simply glued on to the surface of the leaf. Such eggs come off when the shoot is placed in alcohol.

By virtue of their position the eggs are well protected from unfavourable climatic conditions, and as they are anchored into the plant tissue by means of their stalks they cannot be washed off by rain. Further, on hatching the nymphs obtain a rich supply of food.

Egg-laying records were obtained by confining, in sleeves placed on young plants, couples of freshly emerged adults. A single pair was placed in each sleeve. In captivity a female may lay over 800 eggs, and continue egg-laying for about two months. The statement below gives details about oviposition :—

Daily egg laying records of D. citri *during March, April and May (at Lyallpur).*

(The period of greatest activity.)

Date.	March 1923				April 1923					May 1918			
	A.*	B.	C.	D.	A.	B.	C.			E.	F.	G.	H.
1	9	Em.			0	4	11			15	15	29	Em.
2	10	4	Em.	Em.	0	3	7			17	25	43	0
3	21	11	10	0	0	14	9			32	32	35	0
4	25	12	7	15	5	4	3			55	15	40	27
5	20	25	21	16	6	5	D			45	85	57	31
6	42	12	26	41	7	5	..			17	25	..	29
7	10	32	7	30	9	3	..			53	27	..	71
8	15	15	6	15	10	12	..			50	15	..	39
9	0	25	5	2	4	4	..			15	13	..	40
10	0	24	1	9	5	0	..			25	23	D.	70
11	16	14	2	29	7	10	..			D.	21	..	20
12	17	5	0	35	9	12	..			..	12	.	10
13	0	0	0	0	0	0	..			..	20	..	8
14	15	2	2	7	23	4	..			..	D.	..	12
15	20	39	4	9	23	25	..			..	..	..	10
16	21	25	25	10	4	3	..			..	..	..	15
17	35	20	7	2	0	0	..	1918		..	..	..	10
18	0	56	6	0	9	7	E.	F.	G.	..	..	..	10
19	35	50	64	0	6	9	..	..	..	..	..	..	5
20	23	25	3	13	7	6	Em.	Em.	..	..	..	..	..
21	23	15	7	2	26	7	0	10	..	..	..	..	..
22	13	18	55	18	22	26	85	75	..	..	..	..	..
23	13	18	55	18	22	12	60	64	Em.	..	..	..	..
24	14	17	55	19	23	22	69	65	75	..	..	..	..
25	15	13	45	21	4	23	40	54	129	..	..	..	..
26	16	12	0	5	25	4	45	60	124	..	..	..	..
27	7	11	15	9	0	25	20	74	95	..	..	..	..
28	2	13	25	10	†	‡	26	30	79	..	..	..	..
29	3	10	16	12	..	..	15	46	25	..	..	..	D.
30	4	9	7	ES	..	..	..	..	..	..	..	..	..
31	1	7	0	..	..	..							

Em.=emerged.
Es.=escaped.
D.=died.
*A emerged on 28-x-22 but did not start oviposition till 1-iii-23.
†A stopped egg-laying on 27-iv-23, but lived till 5-vi-23.
‡B stopped egg-laying on 27-iv-23, but lived 6-vi-23.

	A	B	C	D	E	F	G	H
Total number of eggs laid.	721	790	525	379	684	807	731	407
Total duration of the life of adult.	28-x-22 to 5-vi-23	1-iii-23 to 6-vi-23	2-iii-23 to 5-iv-23	..	21-iv-18 to 10-v-18	21-iv-18 to 11-v-18	24-iv-18 to 14-v-18	1-v-18 to 20-v-18

Hatching. The egg stage occupies from 4 to 6 days in summer and up to 22 days in winter. The nymph comes out of the egg shell through a slit that appears at the

narrower end of the egg. Lees[1] has described a weak spot at the place where the egg-shell bursts. It takes about 20 minutes for the nymph to come out of the egg-shell completely. The empty egg-shell shrivels up into a scale-like structure and remains attached to the plant.

Nymphal instars. There are five nymphal instars. In the younger stages the nymphs are mostly concealed, and are found at the tips of tender shoots. During the later stages they move down the shoot. They do not, however, leave the fresh shoot and are never found on last season's growth. When disturbed, they move about in a slow, steady manner. They can withdraw their long mouth-parts and re-thrust them into the plant tissue quite readily.

Total duration in the nymphal instars varies from 11 to 25 days according to the season, and each instar occupies about 3 days in summer and 4 days in winter, except the first instar which occupies 11 or 12 days in winter.

Statement showing the duration of nymphal instars of D. citri *during Summer and Winter.*

	Summer			Winter	
First instar	26-iv to 28-iv	28-iv to 1-v	28-iv to 2-v	23-xii to 3-i	24-xii to 3-i
Days	2	3	4	11	12
Second instar	28-iv to 30-iv	1-v to 4-v	2-v to 4-v	3-i to 6-i	3-i to 7-i
Days	2	3	2	3	4
Third instar	30-iv to 4-v	4-v to 6-v	4-v to 6-v	6-i to 10-i	7-i to 12-i
Days	4	2	2	4	5
Fourth instar	4-v to 7-v	6-v to 8-v	6-v to 10-v	10-i to 13-i	12-i to 16-i
Days	3	2	4	3	4
Fifth instar	7-v to 10-v	8-v to 11-v	10-v to 13-v	13-i to 18-i	16-i to 21-i
Days	3	3	3	5	5
Total duration	14	13	15	26	28

Life-cycle. From the statement below it will appear that the egg-stage may occupy 3 to 23 days, according to season, the nymphal stages 11 to 25 days, and the adult starts egg-laying soon after emergence. The total life-cycle occupies from 15 to 47 days. The adults live for a long time and have been known to live as long as 189 days.

[1]Lees, A. H. (1916) *Ann. App. Biol.*, II, pp. 251-257.

Statement giving duration of the life-cycle during different months.

Oviposition	Hatching	Days.	Emergence of adult	Days.	Total duration (days)
6-ii-23	28-ii-23	22	16-iii-23	16	38
17-iii-23	24-iii-23	7	8-iv-23	15	22
16-iv-23	22-iv-23	6	3-v-23	11	17
24-iv-18	28-iv-18	4	9-v-18	11	15
26-iv-18	1-v-18	5	12-v-18	11	16
9-v-19	15-v-19	6	28-vi-19	13	19
23-v-23	27-v-23	4	7-vi-23	11	15
9-vi-23	14-vi-23	5	29-vi-23	15	20
1-vii-22	4-vii-22	3	18-vii-22	14	17
20-vii-22	25-vii-22	5	8-viii-22	14	19
10-viii-22	15-viii-22	5	30-viii-22	15	20
1-x-22	10-x-22	9	29-x-22	20	29
2-xii-19	23-xii-19	21	16-i-19	24	45
2-xii-19	24-xii-19	22	18-i-19	25	47

SEASONAL HISTORY.

Eggs, nymphs and adults of *D. citri* are found on Citrus plants throughout the year, and no definite hibernation in any particular stage has been observed. During winter, which is very severe in most parts of the Punjab, the life-cycle is much prolonged (see above) and the insects are not very active except during the warmer parts of the day.

Adults have been known to live throughout the winter and lay eggs only in the spring when the new leaves have appeared. The Psylla becomes active about the end of February and its numbers increase very rapidly during March and April, when numerous eggs are laid and large colonies of nymphs in all stages of development are found on young shoots, flowers and new leaves. During May and June the insects are found mostly as adults, and in July—when the rains start and there is another outburst of fresh growth—these congregate on tender shoots and lay eggs, and nymphs hatch out in large numbers. The pest begins to disappear about the middle of October and during December and January it is present in very small numbers. This is due partly to the low temperature which retards development and partly to attacks of parasites which have been active all this time. (The facts mentioned above are true for Pusa also.)

The number of generations in the year. To find out the number of generations in the year observations were started on 1st July 1922 and continued till 29th June 1923. Eggs observed on an orange shoot were sleeved *in situ*. When adults emerged they were sleeved on to fresh shoots which had been previously

examined and found free from all stages of the pest. The following Table shows the numbers of generations which were actually reared :—

Number of generations	Date of oviposition	Date of hatching	Date of emergence	Duration of life-cycle (days)	Remarks
1	1-vii-22	4-vii-22	18-vii-22	18	
2	20-vii-22	25-vii-22	8-vii-22	19	
3	10-vii-22	15-vii-22	30-vii-22	20	Adults emerging on 30-viii-22
4	1-x-22	10-x-22	29-x-22	29	did not lay eggs till 1-x-22.
5	6-ii-23	28-ii-23	16-iii-23	38	Adults emerging on 29-x-22,
6	17-iii-23	24-iii-23	8-iv-23	22	did not lay eggs till 6-ii-23.
7	16-iv-23	22-iv-23	3-v-23	17	
8	23-v-23	27-v-23	7-vi-23	15	
9	9-vi-23	14-vi-23	29-vi-23	20	

Thus in these experiments nine generations were definitely traced during the year. It is, however, interesting to note that the adults which emerged at the end of August did not lay eggs for one month, *i.e.*, until October, and those which emerged at the end of this month did not oviposit for over three months. As mentioned above, the insect does not undergo hibernation and in nature all the stages are met with throughout the year. Failure to lay eggs is, therefore, most probably attributable to the fact that during these periods young shoots were not available. If this interpretation is correct, then there is a possibility of at least two or three more generations during the year. As adults live for a very long time and continue egg-laying for a period which may extend to over two months there is considerable overlapping and no definite broods can be recognized.

HABITS AND BEHAVIOUR.

Habits of the nymphs. The young nymphs remain congregated on the young shoots close to the seat of oviposition. For a few days they continue to feed inside the unopened leaves, between the axillary bud and the stem or on the tender portion of the stem itself. When overcrowded, they crawl down the stem and gain subsistence from larger leaves and thicker parts of the tender stem. They are, however, confined to the fresh shoots. As a rule nymphs do not move much, but when disturbed or when migrating to a lower portion of the stem, they walk with a quick steady pace. The nymph sucks cell sap and exudes from its anus a thick sugary liquid which is covered over with a waxy secretion of the circumanal glands. This exudation appears as a thick translucent cord. When it has attained a certain size, the insect moves its abdomen from side to side in a characteristic fashion as if rubbing off this matter, and continues to do so till the wax-covered globule of 'honey-dew' drops off. In cases of bad attack the ground under the trees appears white on

account of the drops of this sugary excretion. When this matter falls on the leaves it gives them a shining appearance and stickiness. Later on fungus grows on this sugary material and the leaves appear to be covered over with a black sooty deposit.

Habits of the adults. The adults do not fly very far. They are usually found, in large numbers, sitting on the lower sides of the leaves with their heads almost touching the surface and the rest of the body raised up. The axis of the body thus forms an angle of 30° with the leaf. They do not possess the power of sustained flight and, unless disturbed, they do not move. Their movement consists of a leap in which the hind legs play an important part and the wings act as parachutes. When fresh leaves appear, the adults congregate on these, moving about quickly as if surveying the situation for oviposition. It has been noticed that if placed in a glass tube the adults move towards the window and congregate towards the top of the tube. Thus in captivity they are positively heliotropic and negatively geotropic. The migration of adults to fresh shoots, however, does not seem to be a response to either of these two stimuli. It may be repeated that adults will not lay eggs except on tender portion of the shoots.

SEASONAL HISTORY OF THE CITRUS TREES.

The Citrus trees are evergreen and continue to produce fresh leaves throughout the greater part of the year. The seasons for flushing, however, in the Punjab and at Pusa are the spring (end of February to April) and the rainy season (July and August), when fresh shoots appear and leaves are produced in great abundance. In most varieties the floral buds begin to appear during the last week of February and flowers continue to open till about the end of March. The fruit sets in March. In the case of oranges and maltas, the fruit remains on the tree for the rest of the year ripening in November and December and developing its finest flavour in January and February of the following year. The acid varieties ripen earlier.

The exact dates of flushing, flowering and fruiting vary with the locality, season, and variety, but the above may be taken as the typical seasonal history of the host. In some varieties not only the leaves but flowers and fruits continue to appear and fruits of all sizes are present on the plant throughout the year.

DAMAGE.

D. citri neither produces galls nor causes any malformation of the plant tissues. The only external sign of injury is defoliation and death of the shoots attacked and the drying up of the branches. On badly infested trees the continual feeding of myriads of insects is, in itself, a very great drain on the food-supply of the plant, but most probably some poison is also injected into the tissues of the host and this produces the more serious results. This is evident from the fact that the fruit of

the infested tree is dry and insipid to taste, and branches other than those actually attacked also dry up. Besides, young shoots are killed, old leaves fall off and in course of time an attacked tree is denuded of leaves altogether. The period of the greatest activity of the insects and most rapid increase in their numbers corresponds with that of the sprouting of new shoots and appearance of new leaves. The greatest damage is therefore done at this stage. In the Punjab it is during March and April that the attack is most severe, and every fresh crop of leaves and buds is killed. During the first year of attack the damage is not very marked and the trees do not appear much affected. The yield, however, falls, and some top branches dry up. During the second year of attack, if the pest has been allowed to develop unchecked, all the new shoots are destroyed, and most of the branches are left without leaves and the tree begins to dry up. Very little fruit is borne and that too is of small size, insipid and dry. During the third season, there is neither leaf nor fruit on the trees and, if no remedial measures are employed, the trees begin to die. At Sargodha where the pest had been allowed to multiply unchecked for several years, it was not an uncommon sight to see large trees reduced to dry twigs without a leaf.

The citrus growers, being ignorant of the potentialities for damage possessed by these small insects, attribute the failure of crop to other causes and the real culprits remain undetected for a long time and are often only noticed when they have established a firm foothold. The extent of damage which *D. citri* is capable of doing may be judged from the following two cases which were carefully studied and for which figures are available :—

Locality	Year	Income	Remarks
		Rs.	
1. Sargodha	1915	450	Average income per year before the attack.
	1916	250	Serious attack during this year.
	1917	25	Severe attack.
	1918	400	Orchard sprayed in September 1917 and March 1918.
	1919	500	No attack.
	1920	700	No attack.
2. Sargodha	1915	1,200	Normal income before the attack.
	1916	500	Serious attack.
	1917	120	Very little fruit : attack very severe.
	1918	700	Orchard sprayed once during March 1918.
	1919	500	Orchard not sprayed.
	1920	1,300	Orchard thoroughly sprayed early in the season.

PREDATORS AND PARASITES.

So far we have not obtained any parasites from the eggs of *D. citri* and no predators have been noticed. The adult also seems to be fairly free from enemies. The

nymphal stages, however, are subject to the attacks of a number of predators and parasites, which play a very important part in keeping this pest in check.

Predators. Of the more common predators on *D. citri* nymphs the following may be mentioned :—

Coccinellidae :

Coccinella septem-punctata, Linn., is a very common species. It usually feeds on Aphids. Both the larvae and adults have been noticed to feed on the nymphs of this Psylla. A complete life-cycle occupies about 17 days. These beetles, therefore, multiply rapidly and are capable of doing enormous good.

C. repanda has similar habits. It, however, does not occur in such large numbers as the above mentioned species.

Chilomenes sexmaculata occurs in fairly large numbers and does useful work.

Chilocorus nigrita also occurs in very large numbers feeding on the nymphs of Psylla.

Brumus suturalis is a very small beetle. It is not very common and has been noticed in only a few orchards.

Syrphidae : A Syrphid fly was also found in large numbers, the maggots of which were observed feeding on the larger nymphs. In March and April, when its food supply is abundant, the entire life-cycle occupies 12 days.

Chrysopidae : The larvae of *Chrysopa* sp. were also present in large numbers feeding on the nymphs.

Besides the above, certain Spiders and Mites are also found feeding on adults of Psylla.

Parasites. The parasites of the nymphal stages, however, play a more important part than the predators. So far nine different Chalcidoid parasites have been reared from the nymphs of *D. citri*. The most important of these is *Tetrastichus radiatus*, Waterston[1]. The precentage of parasitization is often very high and as many as 95 per cent. of the nymphs may be attacked. From the observations made by us it seems likely that in all those localities where *D. citri*, although present, does not increase in numbers sufficiently to cause any serious damage, the credit of keeping the pest in control is mainly due to this parasite. Unfortunately a number of hyperparasites have also been noticed.[2]

CONTROL MEASURES.

As mentioned above, the predators and parasites play a very important part in keeping this pest in check, and every effort should be made to increase the number of these beneficial insects.

For immediate relief, however, spraying is recommended. Care should be taken that this measure is not employed at a time when the percentage of parasitization is very high. Spraying has been tried extensively and has proved thoroughly

[1] Waterston, J. (1922). On the Chalcidoid Parasites of Psyllids. *Bull. Ent. Res.*, XIII, pp. 41-58.
[2] Husain and Dina Nath (1923). *Proc. Fifth Ent. Meet.*, pp. 122-135.

effective. Any good contact poison will serve the purpose. We recommend tobacco decoction and rosin compound, as these can be prepared on the spot, are easy to work with and the ingredients are available everywhere. Crude oil emulsion has also given very good results, but, taking into consideration the freight, it becomes expensive. During our experiments tobacco decoction was prepared in the following manner :—

A *seer* (2 lb.) of tobacco refuse (leaves, stems, dust, etc.) was soaked in 10 seers of water for 24 hours, after which it was strained, and to the liquid was added about 4 *chataks* ($\frac{1}{2}$ lb.) of cheap soap cut into small pieces, the solution being stirred to dissolve the soap thoroughly. This stock solution was diluted with 8 parts of water for spraying purposes.

Tobacco decoction is more useful for spring spraying against the nymphs. It does not injure the plant at all.

Rosin compound is particularly efficacious against the adults during winter spraying. It is prepared according to the following formula :—

Rosin, 2 seers.
Soda, 1 seer.
Solignum or Sanitary fluid, 1 seer.
Water, 4 gallons.

Rosin and soda are placed in a vessel and sufficient water to cover is added, and the whole is heated over a slow fire till it boils, and the boiling is continued till rosin and soda are completely dissolved. During the process water is added slowly all the time, until 4 gallons have been added. The compound is tested from time to time to see if it mixes well with water. Before it is fully cooked a drop of it when put in water forms a milky emulsion ; when, however, it is ready it mixes without producing milkiness. This stock solution is diluted with 6 parts of water. Solignum is added to the solution and well mixed.

During the spraying operations in the Punjab a Four Oaks Lime washing machine was used, and on an average a gallon of the spraying mixture was quite enough for one tree.

Spraying schedule. It is very important that spraying should be done at the right time.

A thorough spraying with rosin compound during the winter will kill most of the adults. The trees must be very carefully sprayed and a good pressure maintained, and the underside of the leaves where insects congregate must receive special attention. It may be necessary to repeat the operation. If Winter spraying has been done satisfactorily there will be no need to undertake Spring spraying, but in case a few adults have survived or have migrated from other orchards, they must be dealt with. This should be undertaken when most of the nymphs have hatched out and the adults of the new brood have not yet emerged. In the Punjab, March is the best time for this. Tobacco decoction has given very good results. As the nymphs are mostly concealed in the fresh shoots, spraying should be directed towards

these parts. A very fine mist should be produced so that the insecticide reaches everywhere. The eggs are more difficult to kill, but if the attack is serious, a third spraying may be done after about a week or so, to kill any nymph that may have hatched.

During 1925-26 about 5,000 trees were sprayed and the efficacy was from 74—95 per cent., rosin compound giving the best results. (Text fig. 3)

Fig. 3. A branch after spraying showing dead hoppers.

PREVENTIVE MEASURES.

The plants which receive proper cultivation are able to withstand the attacks of pests much better than sickly plants, and it is advisable that attention be paid to cultural methods in pest control.

Citrus hedges are commonly grown in most parts of the Punjab. A well-trimmed hedge is always producing fresh leaves which provide food to the nymphs and on which the adults oviposit. These hedges, therefore, serve as reservoirs for the pests, and in the vicinity of citrus orchards such hedges should be discouraged.

The nurserymen who sell Citrus plants to the orchard owners have no idea of the importance of selling pest-free stock, and it is not uncommon to find seedlings covered with nymphs of Psylla being offered for sale and bought. Steps should be taken to legislate against the sale of plants attacked by Insect Pests.

SUMMARY.

Diaphorina citri, Kuw., is a serious pest of Citrus plants in many parts of India. The pest attacks young tender shoots and kills them. In course of two or three seasons, the tree is completely defoliated and begins to dry up. During severe attacks the fruit does not set or drops off, and what is left is dry and insipid.

Eggs are deposited on the young shoots, usually in clusters within the folds of unopened leaves, between the petioles of leaves and buds, and buds and stem. The nymphs that hatch out remain congregated on these tender shoots and kill them. Eggs are not laid on old leaves and the nymphs are never found except on the fresh growth. There are five nymphal instars and the life cycle takes from 15 to 20 days in summer. There are about nine generations in the year. The female may lay up to 800 eggs and therefore the increase in numbers is very rapid.

Several different predators and parasites help to keep this pest in check, and of particular importance is *Tetrastichus radiatus*, a Chalcidoid parasite.

Spraying is an effective method of control ; rosin compound and tobacco decoction have given good results.

Attention should be paid to proper cultivation and Citrus hedges should not be grown around Citrus orchards, because these hedges act as reservoirs for fresh infestations of Citrus Psylla.

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